I.R. Optical Absorption of Antimony Films

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(Z. Naturforsch. **28 a**, 1969—1970 [1973]; received 5 July 1973)

Measurements of the optical constants give information about the electronic structure of antimony. Quantum transitions between the energy bands play a significant role in I.R. absorption. The width of the energy gap can be obtained from such measurements.

Measurements have been done on polycrystalline antimony films deposited by thermal evaporation onto potasium bromide discs. The films were prepared in a vacuum of 10^{-5} torr at an evaporation rate of 15 Å per second. Optical transmission measurements were made over the range $2-20$ microns using a double beam UR-10 Spectrophotometer, which gives values of transmission accurate to 1%. The thicknesses of evaporated films (from 200 to 3000 Å) were determined by multiple beam interferometery [1].

The variation of the transmittance of unannealed films of antimony, on pottasium bromide substrate, with the wavelength is shown in Figure 1. It is noticeable that the wavelength at the transmittance maximum increases with increasing film thickness.

Following Tubbs [2] and Brattain [3] the absorption index k and the index of refraction n for a thick absorbing film ($4\pi k d > \lambda$) is given by

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2},$$

$$T = \frac{16\, n_1 (n^2+k^2)}{[(n+n_1)^2 + k^2][(n+1)^2+k^2]} \exp\left\{-\frac{4\pi k d}{\lambda}\right\}$$

where T, R are the intensities of the transmitted and reflected light, n_1 is the refractive index of the substrate and d is the film thickness.

The dependence of k and n on λ, for thick antimony films ($d > 1200$ Å) calculated by the above formula, is shown in Figure 2. The value of k and n where the k, λ and n, λ curves cross is about 3.8.

Woltersdorf [4] made measurements on unannealed antimony deposits. The k's and n's derived from his measurements are much smaller than those obtained for annealed deposits [5].

Knowing the optical constants n and k, one can calculate the coefficient of energy absorption using

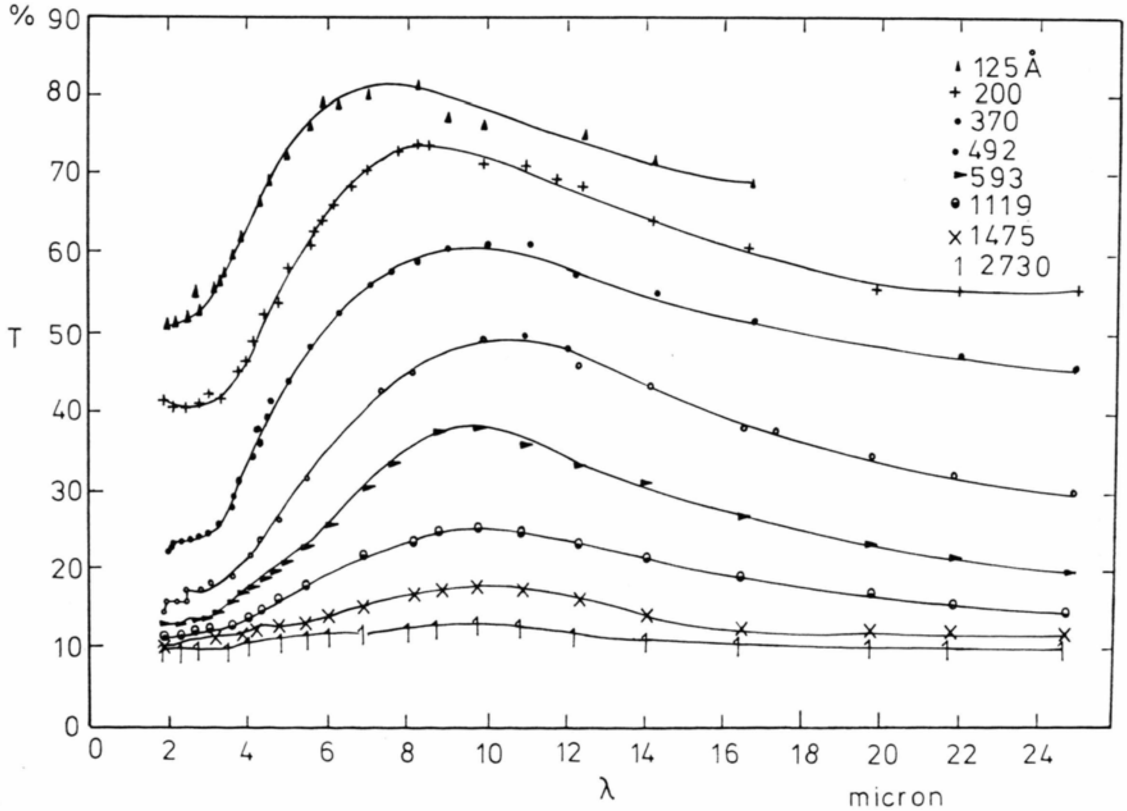

Fig. 1. The variation of the transmittance of unannealed antimony films with the wavelength.

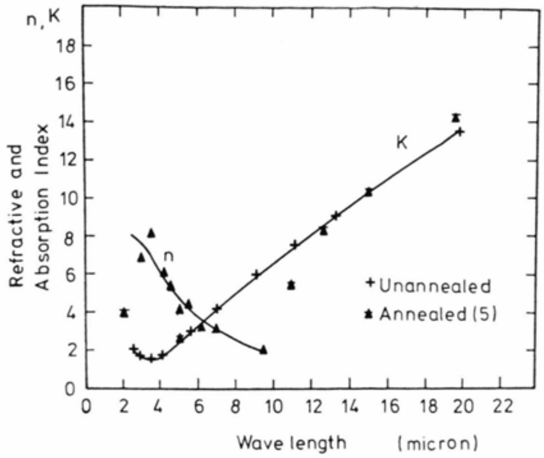

Fig. 2. The dependence of the refractive index and absorption index on the wavelength.

the well known formula [6]

$$A = 4\,n / [\,(n+1)^2 + k^2]\ .$$

The curve $A(\lambda)$ (Fig. 3) has a very evident maximum which should be ascribed to the presence of interband transitions. From the shape of the absorption curve it is clear that the energy gap corresponds to less than 11 micron. This agrees with the measurements of Lenham and Trehrene [7] for antimony crystals in the basal plane.

From the position of the maximum of the absorption coefficient one can find the width of the energy gap $\Delta E = h\,c/\lambda_{\rm m}$

$$\lambda_{\rm m} = 6\,\mu\,, \quad \Delta E = 0.207 \text{ eV}\,.$$

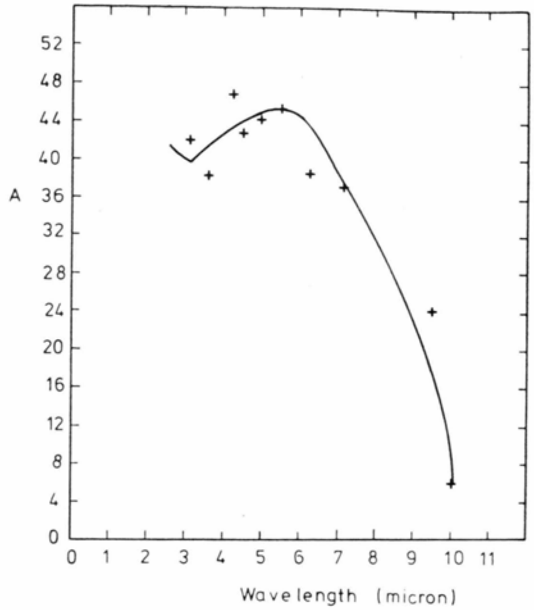

Fig. 3. The variation of the coefficient of energy absorption with the wavelength.

This result agrees with that of Smith [8], who finds theoretically that for antimony films ΔE lies in the range of $0.15 - 0.20$ eV.

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